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Hydrology and Earth System Sciences Discussions

Interactive comment on "Assessment of the indirect calibration of a rainfall-runoff model for ungauged catchments in Flanders" *by* N. De Vleeschouwer and V. R. N. Pauwels

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We want to express our gratitude to the reviewer for the constructive review. First, the general comments will be discussed. Then, the terminology and detailed comments will be addressed.

Answers to general comments

- The choice of the objective function (RMSE of the root squared spectral densities) is based on the results found in Quets et al. [2010]. Indeed it is not mentioned in the text which assumptions are made about the error between the root squared spectral densities of the observed and modelled timeseries. The authors do not find it straightforward to make explicit assumptions about this error. When the root squared spectral densities of a synthetic time series and that same time series with a certain added white noise are compared, a quasi symmetric distribution is found. However it is not normally distributed (it failed a normality test). The same experiment has been carried out for the logaritmic spectral densities, but with the same result. In the revised version of the paper, we will mention the fact that the normality assumption does not hold for the squared spectral densities when it is assumed that the time domain residuals are considered normal.
- Because the spectral density spectrum is calculated by a Fourier transformation of the correlation function, a matching of the spectral density spectra will result more in a matching of the correlation structure of the observed and modelled timeseries (Montanari, 2007). So a calibration in the spectral domain is more matching the shape characteristics of the observed and modelled time series. Because the spectral density at k=0 is an estimate of the timeseries mean, the bias between the observed and modelled time series is explicitly minimized as well. This can clearly be seen in figure 7 (subfigure at second row and first column). By giving a small (experiment F-D-3-3) or no (experiment F-D-3-2) weight to the spectral density at k=0 in the objective function, the bias between the observed and modelled discharge is remarkably higher in the calibration period.

Answers to terminolgy comments

1. The term *'contemporaneaous'* will be replaced by *'concomitant'* as it is more widely used.

2. When introducing the term *'indirect calibration'* a reference will be made to Montanari and Toth [2007] as the concept was first used in the context of spectral calibration in this paper. No specific references are made in this paper to the general concept of *'indirect calibration'*.

3. The spectral terminology used in this paper was adopted from Montanari and Toth [2007]. At this point we would prefer to not alter the terminology we have used, since this terminology is frequently used in publications in the hydrological sciences focusing on spectral analysis. However, if it would really be deemed necessary to modify the terminology, we are certainly willing to do so.

4. It will be indicated in the paper that the calculation of the density spectrum based on a discharge time series is already an estimate of the true property because of the time series finiteness and the observation error. The distinction with the spectrum estimate uncertainty caused by the absence of an autochtone time series in ungauged basins will be more emphasized.

Answers to detailed comments

1. As noted by all three reviewers some key references are not discussed in the literature review of the discussion paper. The following references will be added to the paper in order to give a more accurate overview of published research in the context of parameter estimation in ungauged catchments:

- Bardossy, A.: Calibration of hydrological model parameters for ungauged catchments, 25 HYDROLOGY AND EARTH SYSTEM SCIENCES, 11, 703-710, 2007.
- Castiglioni, S., Lombardi, L., Toth, E., Castellarin, A., and Montanari, A.: Calibration of rainfall-runoff models in ungauged basins: A regional maximum likelihood approach, ADVANCES IN WATER RESOURCES, 33, 1235-1242, doi:10.1016/j.advwatres.2010.04.009, Workshop on New Frontiers of Hydrology, Rome, 30 ITALY, JUL, 2009, 2010.
- Merz, R. and Bloschl, G.: Regionalisation of catchment model parameters, JOURNAL OF HYDROLOGY, 287, 95-123, doi:10.1016/j.jhydrol.2003.09.028, 2004.
- Oudin, L., Andreassian, V., Perrin, C., Michel, C., and Le Moine, N.: Spatial proximity, physical similarity, regression and ungaged catchments: A comparison of regionalization approaches based on 913 French catchments, WATER RESOURCES RESEARCH, 44, doi:10.1029/2007WR006240, 2008.
- Parajka, J., Merz, R., and Bloschl, G.: A comparison of regionalisation methods for catchment model parameters, HYDROLOGY AND EARTH SYSTEM SCIENCES, 9, 157-171, 2005.
- Post, D. and Jakeman, A.: Relationships between catchment attributes and hydrological response characteristics in small Australian mountain ash catchments, HYDROLOGICAL PROCESSES, 10, 877-892, doi:10.1002/(SICI)1099-1085(199606)10:6h877::AID-HYP377i3.0.CO;2-T, 1996.
- Seibert, J.: Regionalisation of parameters for a conceptual rainfall-runoff model, AGRICULTURAL AND FOREST METEOROLOGY, 98-9, 279-293, doi:10.1016/S0168-1923(99)00105-7, 1999.
- Vogel, R. and Sankarasubramanian, A.: Validation of a watershed

model without calibration, WATER RESOURCES RESEARCH, 39, doi:10.1029/2002WR001940, 2003.

2. - A short exposition will be added to the paper wherein the Whittle likelihood estimator is compared to the simplified objective function used in this paper. The choice for the more straightforward objective function will be explained.
   - In section 2 *'Spectral properties: mathematical background'* the consequence of not using the more commonly known autocorrelation function but equation 3 on the spectral density spectrum will be explained. This will indeed make the link between the drainage area and estimated density spectrum more comprehensible in section 5.1 *'Case of spatial gauging divergence'*.

3. Periodicity will be replaced by stationarity.

4. We would prefer to keep the explanation of the calibration algorithm very brief, as it has already been explained in other publications to which we refer. As the nature of the calibration algorithm is stochastic, which is the case for many calibration algorithms, repeating the method a number of times will increase the chance that a good solution is found (we can never guarantee that this is the optimal solution). We will clarify this in the text first.

5. The evaluation criteria will likely be influenced by the length of the calibration and validation period. Because the objective of this paper is to assess the overall performance (by using aggregate metrics) of the hydrological model after indirect calibration throughout the year, an evaluation period of at least one year was proposed by the authors. We will more emphasize the fact that the overall performance is evaluated.

6. The Nash-Sutcliffe coefficients for daily discharge forecasts will be calculated. The average difference with the hourly Nash-Sutcliffe coefficients will be shortly

mentioned. We believe that this information will clarify the impact of the model time step on the statistics of the results. We would prefer not to add another figure, since this will not provide significant new insights in the model performance.

7. By considering the spectral densities at k=0 in the objective function a bias reduction is explicitly incorporated in the calibration process. However, the overfitting hypothesis is based on the length of the correlation function used to estimate the spectral densities, which in turn influences the amount of spectral densities for $k>0$ incorporated in the objective function. Correlation function values at higher lags represent more noise effects than physical system characteristics. If longer correlation functions are considered, more weight is given to noise effects in the calibration process. The term overfitting actually denotes overfitting of the autocorrelation structure or thus shape characteristics of the observed and modelled time series. We agree that it would be better to just mention the prior reasoning instead of using the term overfitting, which can give the impression that the actual timeseries values are overfitted. We will modify this in the revised version of the paper.

8. NDIs will be replaced by NDIr, NDIb will be replaced by NDIs.

9. Page 121 line 12: rather lower will be replaced by rather low.

10. *'a certain discharge signature'* denotes *'a particular shape of the hydrogram'*. For example would this calibration approach be more successful in catchments where the hydrogram is characterized by a short time to peak, or a long recession period.

11. We prefer to keep figure 7 the way it is presented now. That way the indicator values can directly be read from the figure.

12. - *E* will be replace by E in mathematical expressions.

- 2) Sdon will get a hat in expression 11 because it's also an estimated variable.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 103, 2013.